

UNCLASSIFIED

AD-A271 100

UNCLASSIFIED

AR-008-148



DEPARTMENT OF  
DEFENCE

2

DSTO

Electronic Warfare Division

DTIC

ELECTE  
OCT 20 1993

S A D

GENERAL DOCUMENT  
ERL-6703-GD

DESIGN ASPECTS AND PARAMETRIC CHARACTERISATION  
OF A NEUTRAL RARE GAS LASER

by

Kenneth J. Grant

\*Original contains color  
plates: All DTIC reproductions  
will be in black and  
white.

This document has been approved  
for public release and sale; its  
distribution is unlimited.

93-24727

UNCLASSIFIED

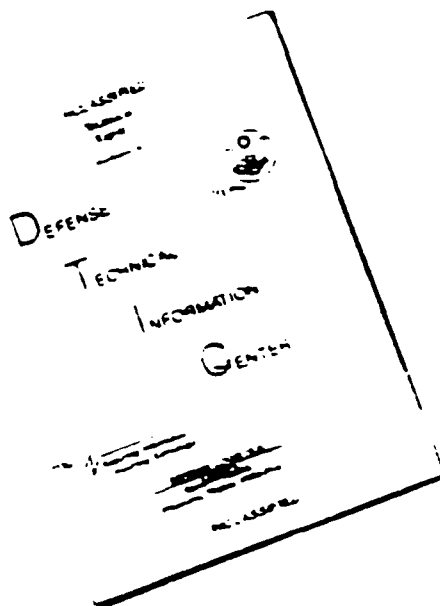
93 10 18 025

APPROVED FOR PUBLIC RELEASE

UNCLASSIFIED

ELECTRONICS RESEARCH LABORATORY

# DISCLAIMER NOTICE



THIS DOCUMENT IS BEST  
QUALITY AVAILABLE. THE COPY  
FURNISHED TO DTIC CONTAINED  
A SIGNIFICANT NUMBER OF  
PAGES WHICH DO NOT  
REPRODUCE LEGIBLY.

*This work is Copyright. Apart from any fair dealing for the purpose of study, research, criticism or review, as permitted under the Copyright Act 1968, no part may be reproduced by any process without written permission. Copyright is the responsibility of the Director Publishing and Marketing, AGPS. Inquiries should be directed to the Manager, AGPS Press, Australian Government Publishing Service, GPO Box 84, Canberra ACT 2601.*

## CONTENTS

## Page No

1	INTRODUCTION.....	1
2	LASER SYSTEM.....	1
3	EXPERIMENTAL LAYOUT.....	1
4	CONTINUOUS WAVE OUTPUT.....	1
5	THE 2 $\mu$ m ATMOSPHERIC WINDOW.....	2
5.1	He-Xe 2.026 $\mu$ m line.....	2
5.2	He-Ar 2.061 and 2.207 $\mu$ m lines.....	2
	ACKNOWLEDGEMENTS.....	3

## TABLES

1	Continuous wave output.....	2
---	-----------------------------	---

## FIGURES

1	Experimental layout.....	4
2	Laser system.....	5
3(a)	Power of He-Xe 2.026 $\mu$ m line versus current.....	7
3(b)	Power of He-Xe 2.026 $\mu$ m line versus He:Xe ratio.....	7
4(a)	Power of He-Ar 2.061 $\mu$ m line versus current.....	8
4(b)	Power of He-Ar 2.061 $\mu$ m line versus He:Ar ratio.....	8
5(a)	Power of He-Ar 2.207 $\mu$ m line versus current.....	9
5(b)	Power of He-Ar 2.207 $\mu$ m line versus He:Ar ratio.....	9

ERL-0703-GD

UNCLASSIFIED

---

THIS PAGE INTENTIONALLY BLANK

---

## 1 INTRODUCTION

A neutral rare gas laser has been built, and used to produce continuous wave output at several wavelengths in the mid- infra-red region. Some of these lines are of particular interest because of their location in the atmospheric window around 2  $\mu\text{m}$ .

The laser design is described, and results are presented of a parametric study of its operating characteristics. Mixtures of He-Ar, He-Kr and He-Xe were used, with total gas pressures in the range 11 - 35 torr. Excitation of the gas was achieved by a hollow cathode longitudinal discharge, with a maximum current of 110 mA. The output power at each wavelength was monitored as a function of the discharge parameters (total pressure, partial pressure ratio, and current), and the output coupler reflectivity, to determine the optimum working regimes.

## 2 LASER SYSTEM

The laser cavity is built around two 0.75" diameter, 1.7 m long invar rods, connected by aluminium blocks on which the optical components are mounted. The rear mirror is gold-plated copper, and there is the choice of three output couplers with reflectivities optimised for the

- (i) 1.8 - 2.7  $\mu\text{m}$ ,
- (ii) 3.5  $\mu\text{m}$ , and
- (iii) 2.7 - 4.8  $\mu\text{m}$  regions (Laser Optics, Inc.).

The output couplers are 25 mm ZnSe concave mirrors with a 15 m radius curvature on the inside face. This configuration means that the cavity is a stable resonator. The external surfaces are anti-reflection coated. The Pyrex discharge tube is 1.3 m long, with a nominal internal diameter of 6.6 mm. A water-cooled jacket around the tube removes excess heat.

The gases used in the laser (He, Ar, Kr >99.999%, Xe >99.995% purity) are delivered to the tube via a moisture trap and 7  $\mu\text{m}$  particulate filters. Fine control is maintained over the pressure of the gases by calibrated needle valves. The total pressure is measured by a capacitance pressure gauge (MKS Baratron type 122A). Ballast resistors of 5 k $\Omega$  and 7.5 k $\Omega$  are in series with the power supply (Industek Pty Ltd) at the cathode and anode ends of the tube, respectively.

## 3 EXPERIMENTAL LAYOUT

The experimental layout is shown schematically in Figure 1, and a photograph of the apparatus is shown in Figure 2. The laser radiation was dispersed by a 0.25 m focal length monochromator (Oriel 77200), and detected by a power meter (Laser Precision Corp., RKP-360). Correction was made for the spectral response of the monochromator. An XT-compatible computer controlled the current and recorded the power.

## 4 CONTINUOUS WAVE OUTPUT

Table 1 lists the lines which have been observed to lase in continuous wave mode. The powers are those under optimum conditions, and transitions are given in Racah notation. The atmospheric absorption coefficients were calculated with the Lowtran 6 model.

Table 1 Continuous wave output

Gases	Wavelength [ $\mu\text{m}$ ]	Transition	Power [mW]	Atmospheric absorption coefficient [ $\text{km}^{-1}$ ]
He-Xe	2.026	$5d[3/2]_1 - 6p[3/2]_1$	13.7	0.21
	2.651	$5d[3/2]_1 - 6p[1/2]_0$	1.2	26.4
	3.366	$5d[5/2]_2 - 6p[3/2]_1$	6.4	0.60
	3.434	$7p[5/2]_2 - 7s[3/2]_1$	4.0	0.23
	3.507	$5d[7/2]_3 - 6p[5/2]_2$	30.0	0.19
	3.650	$7p[1/2]_1 - 7s[3/2]_2$	0.5	0.16
He-Kr	2.523	$4d[1/2]_1 - 5p[3/2]_2$	0.8	7.17
	3.066	$6p[1/2]_1 - 6s[3/2]_2$	4.1	2.00
He-Ar	2.061	$3d[3/2]_2 - 4p[3/2]_2$	0.1	0.21
	2.207	$3d[1/2]_1 - 4p[3/2]_2$	0.3	0.16
	2.397	$3d[1/2]_0 - 4p[1/2]_1$	0.3	0.28

## 5 THE 2 $\mu\text{m}$ ATMOSPHERIC WINDOW

Of the laser lines detected, three were chosen for detailed study because of their location in the 2  $\mu\text{m}$  atmospheric window, viz. the He-Xe 2.026  $\mu\text{m}$  line, and the He-Ar lines at 2.061 and 2.207  $\mu\text{m}$ .

### 5.1 He-Xe 2.026 $\mu\text{m}$ line

The output power of this line is shown as a function of discharge conditions at a total pressure of 11 torr in Figures 3a and b. Figure 3a shows that, for all He:Xe ratios, the power increases monotonically with current up to the maximum of 110 mA. In Figure 3b, power is plotted versus He:Xe partial pressure ratio for a range of currents. For each current there is an optimum He:Xe ratio. The higher the current, the larger the optimum He:Xe ratio ie, the leaner the mixture is in Xe. The maximum power of 13.7 mW is obtained at 110 mA and He:Xe = 80:1. This line will lase with higher total gas pressures, but with lower power. (11 torr is the lowest pressure that will sustain a stable discharge.)

### 5.2 He-Ar 2.061 and 2.207 $\mu\text{m}$ lines

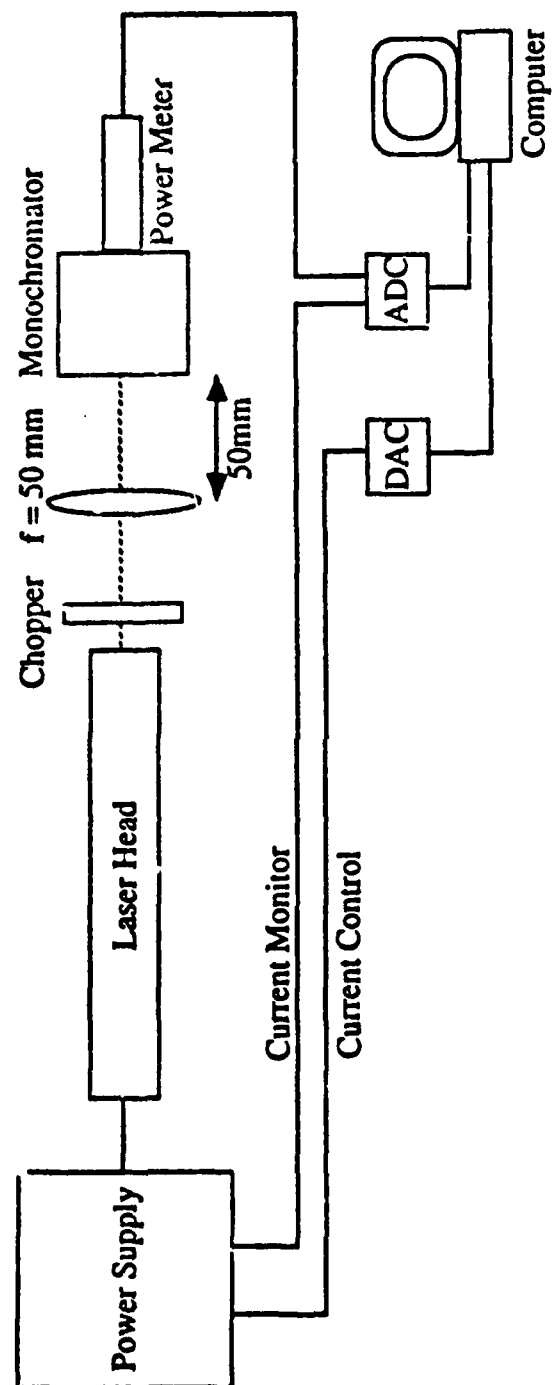
Figures 4 and 5 show the output of the 2.061 and 2.207  $\mu\text{m}$  lines, respectively, as functions of the discharge conditions at 35 torr. These lines have significantly different characteristics to the Xe line, and lase over a much narrower range of conditions. This is particularly so in the case of the 2.061  $\mu\text{m}$  line, which only lases between 35 and 70 mA (Fig. 4a). The 2.207  $\mu\text{m}$  line lases between 15 and 55 mA, with the optimum value being dependent on the He:Ar ratio. Figures 4b and 5b show power versus partial pressure ratio. For each line, the optimum value of He:Ar is dependent on the current. Both lines require gas mixtures which are rich in Ar, and will not lase if He:Ar > 6.5:1.

---

### ACKNOWLEDGEMENTS

The author gratefully acknowledges the contributions of the following: Dr Shane Brunker for fruitful discussions regarding this work; Robert Roseiter for writing the data acquisition software; Fred Buttignol and John Wheatley for their assistance with the high voltage system; and Norm Jeffrey and John Bridgman for the construction of various mechanical components.

---

**Figure 1. Experimental layout.**

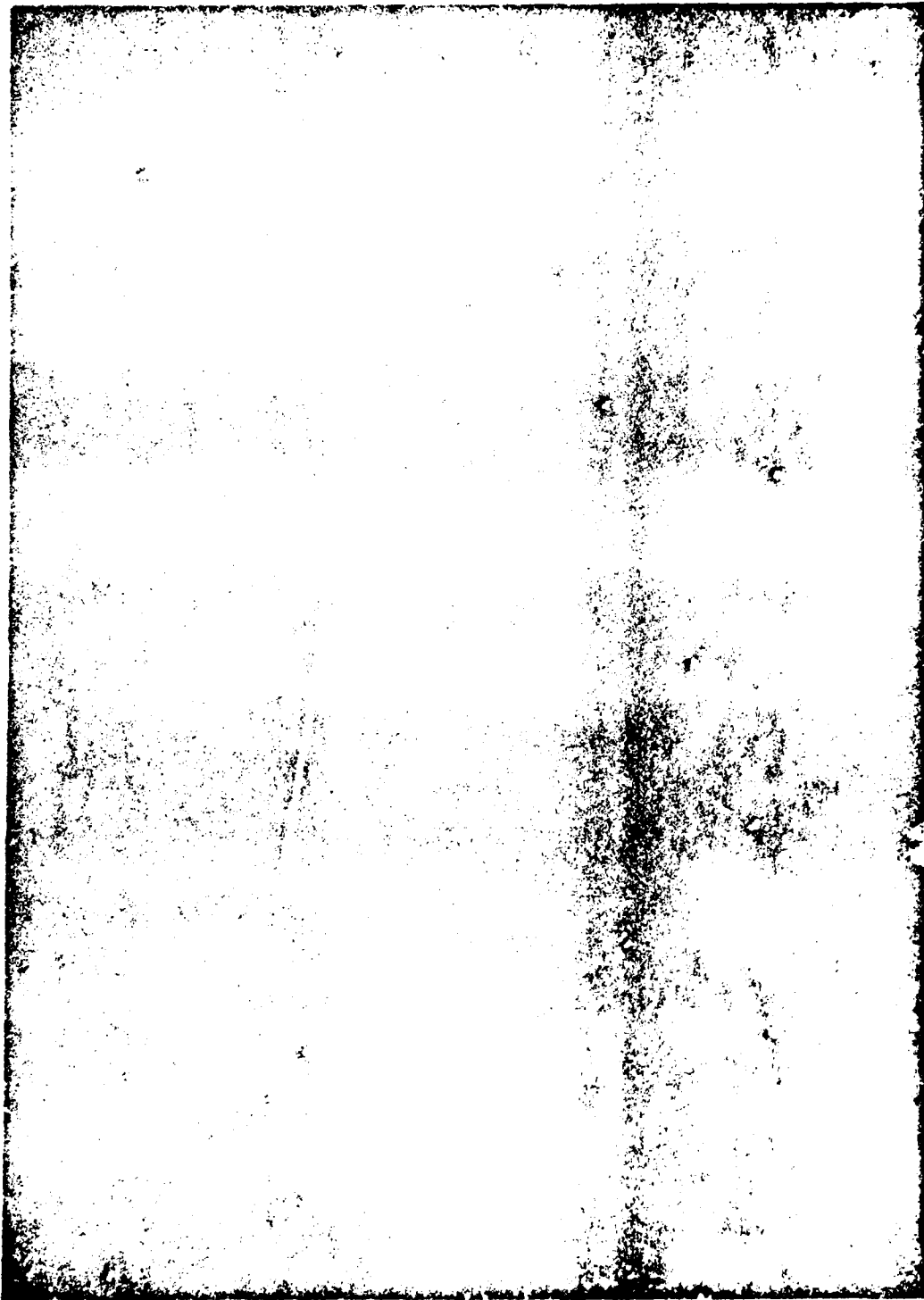
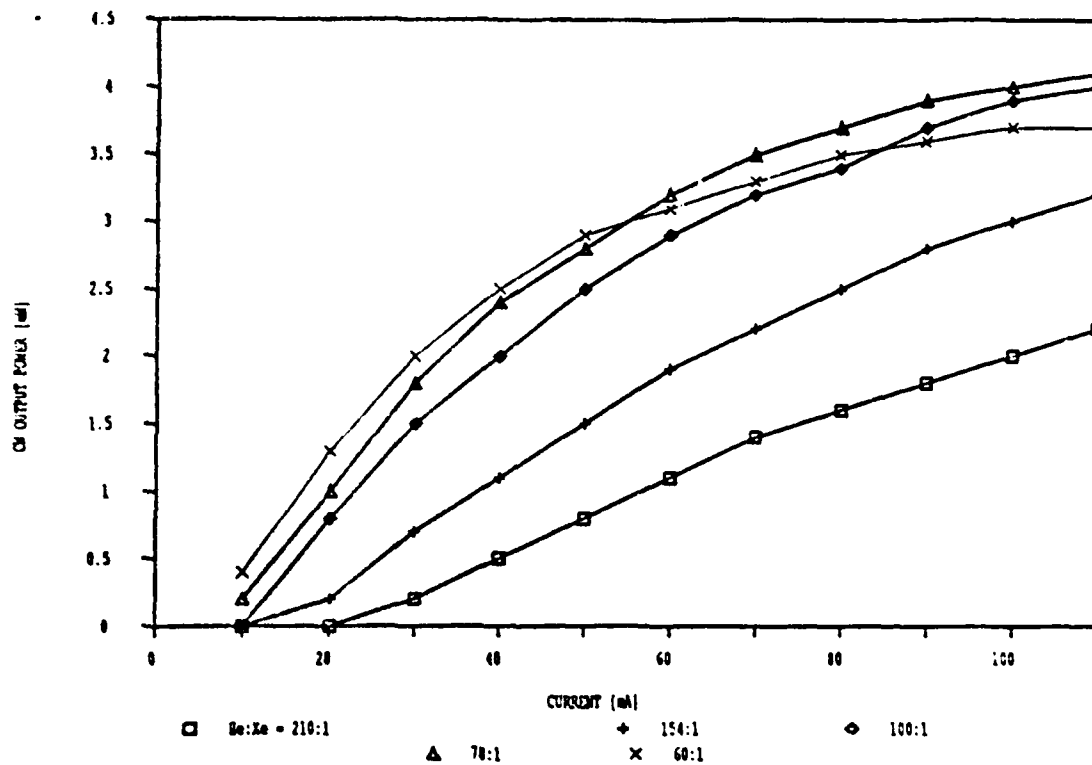
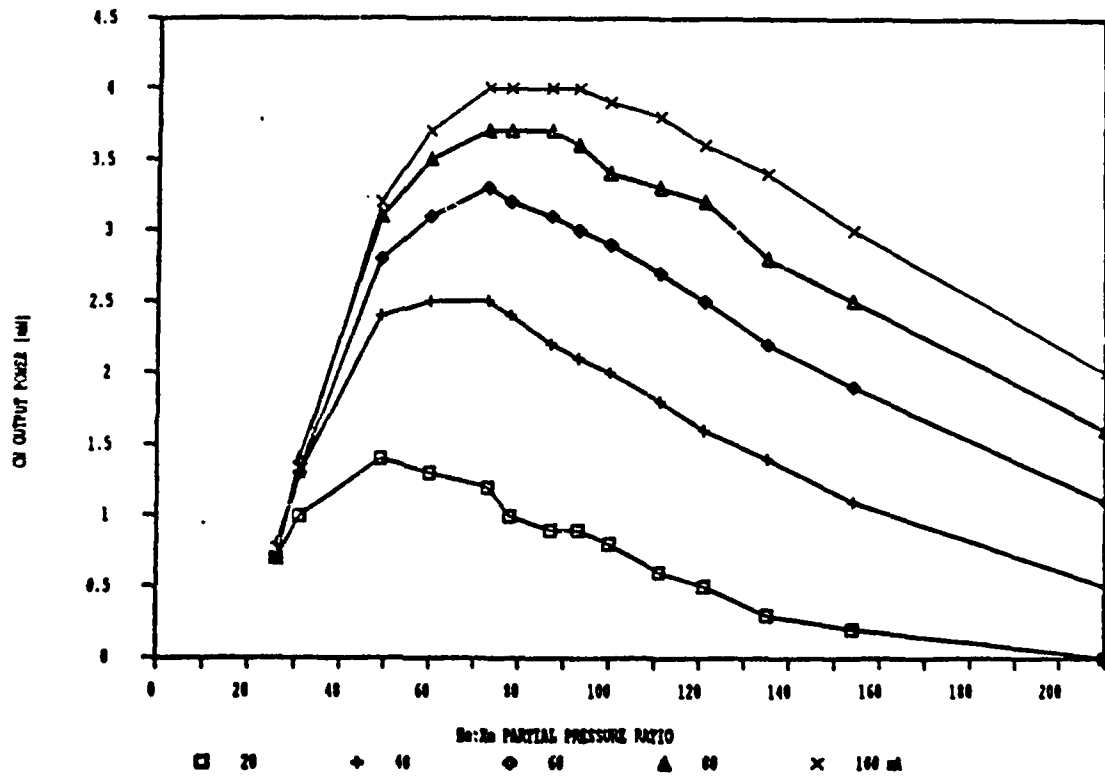


Figure 2 Laser system.

Figure 3(a) Power of He-Xe 2.026  $\mu\text{m}$  line versus current.Figure 3(b) Power of He-Xe 2.026  $\mu\text{m}$  line versus He:Xe ratio.

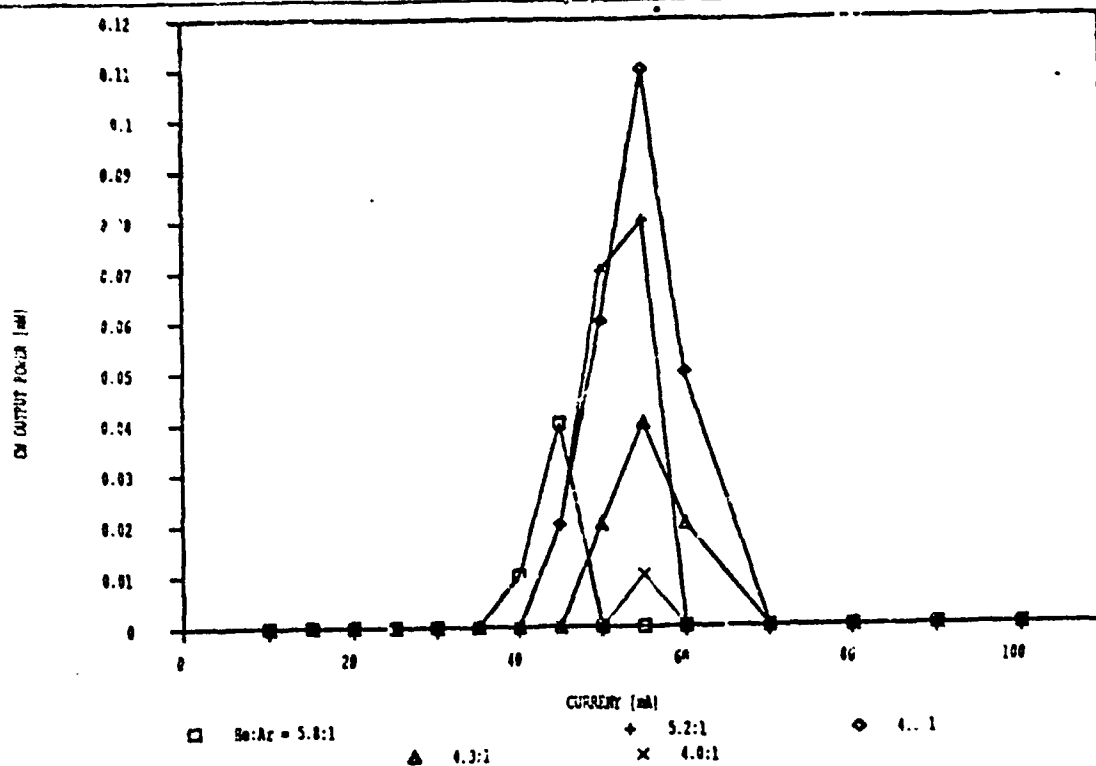


Figure 4(a) Power of He-Ar 2.061  $\mu$ m line versus current.

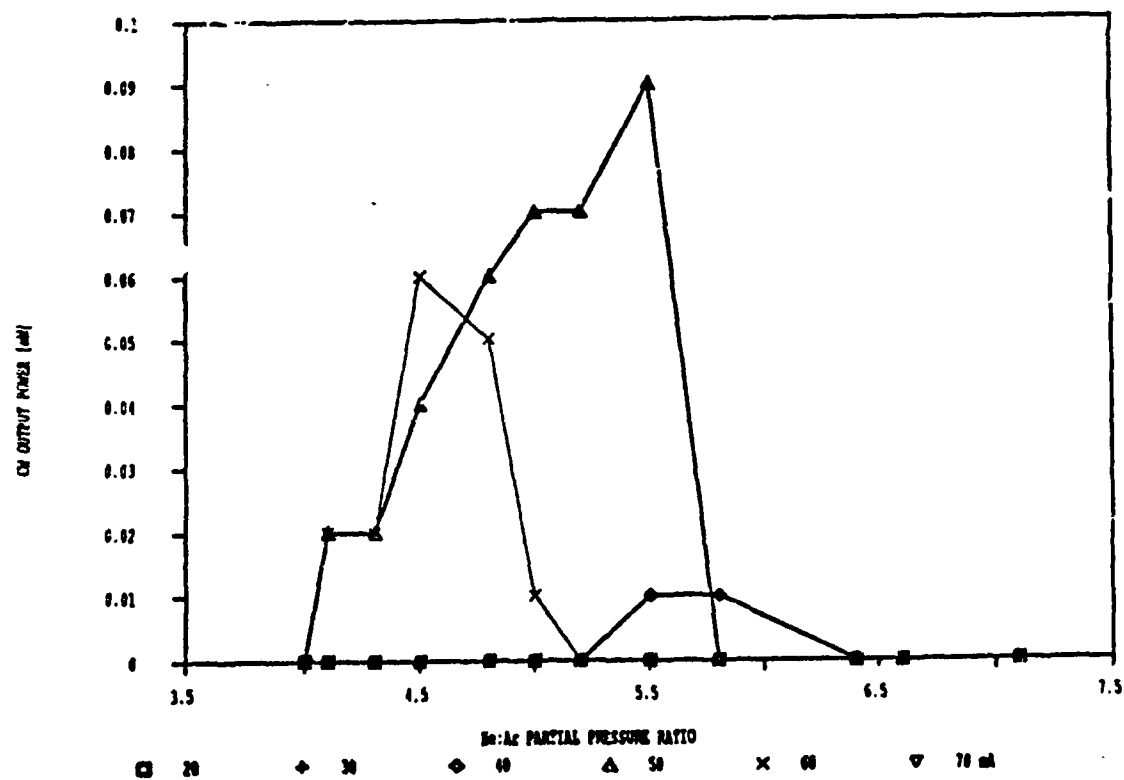
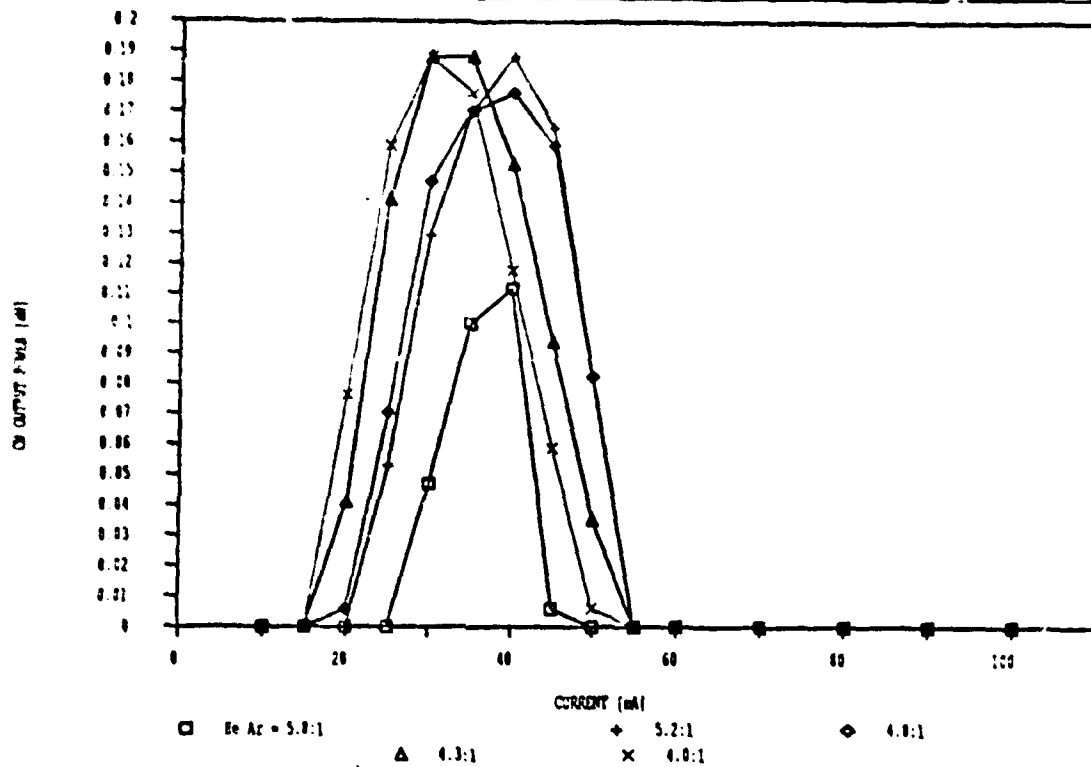
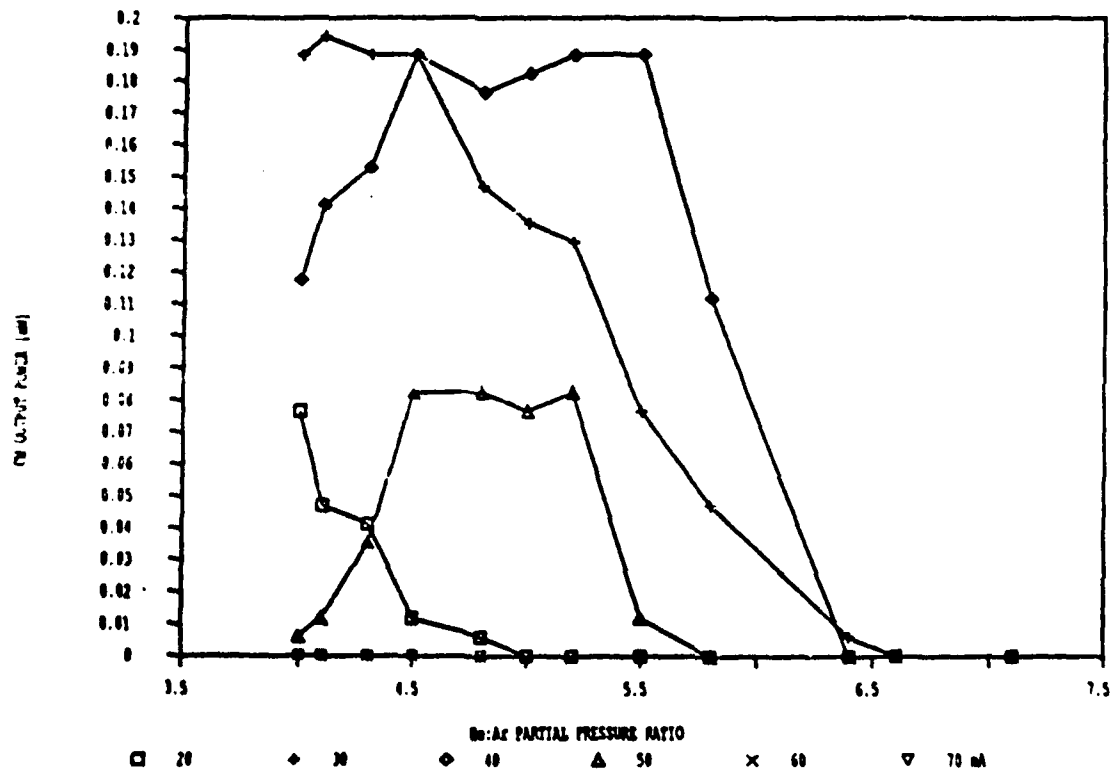


Figure 4(b) Power of He-Ar 2.061  $\mu$ m line versus He:Ar ratio.

UNCLASSIFIED

ERL-0703-GD

Figure 5(a) Power of He-Ar 2.207  $\mu\text{m}$  line versus current.Figure 5(b) Power of He-Ar 2.207  $\mu\text{m}$  line versus He:Ar ratio.

---

ERI-0703-GD

UNCLASSIFIED

---

THIS PAGE INTENTIONALLY BLANK

DISTRIBUTION	No. of Copies
DEPARTMENT OF DEFENCE	
<i>Defence Science and Technology Organisation</i>	
Chief Defence Scientist	) 1 shared copy
Central Office Executive	) for circulation
Counsellor Defence Science, London	Doc Control Data Sheet Only
Counsellor Defence Science, Washington	Doc Control Data Sheet Only
<i>Electronics Research Laboratory</i>	
Director, Electronic Research Laboratory	1
Chief, Communications Division	Doc Control Data Sheet Only
Chief, Information Technology Division	Doc Control Data Sheet Only
Chief, Electronic Warfare Division	1
Research Leader, Electronic Countermeasures	1
Head, Electronic Countermeasures Group	1
Dr Kenneth J. Grant, ECM Group	1
Dr Shane A. Brunker, ECM Group	1
Mr Owen S. Scott, ECM Group	1
Mr Robert J. Rossiter, ECM Group	1
<i>Navy Office</i>	
Navy Scientific Adviser	1
<i>Army Office</i>	
Scientific Adviser - Army	1
<i>Air Office</i>	
Air Force Scientific Adviser	1
<i>Defence Intelligence Organisation</i>	
Scientific Adviser, Defence Intelligence Organisation	1
SA - DC	1
<i>Libraries and Information Services</i>	
Defence Central Library, Technical Reports Centre	1
Manager, Document Exchange Centre (for retention)	1
National Technical Information Service, United States	2
Defence Research Information Centre, United Kingdom	2
Director Scientific Information Services, Canada	1
Ministry of Defence, New Zealand	1
National Library of Australia	1
Australian Defence Force Academy Library	1
Defence Science and Technology Organisation Salisbury, Research Library	2
Library Defence Signals Directorate, Melbourne	1
British Library, Document Supply Centre	1
AGPS	1
Spares, DSTOS, Research Library	6

ERL-0703-GD

UNCLASSIFIED

---

THIS PAGE INTENTIONALLY BLANK

Department of Defence

DOCUMENT CONTROL DATA SHEET

Page Classification
UNCLASSIFIED
Privacy Marking/Caveat

1. AR Number AR-008-148	15. Establishment Number ERL-0703-GD	2. Document Date MAY 1993	3. Task Number DST 92/439
4. Title  DESIGN ASPECTS AND PARAMETRIC CHARACTERISATION OF A NEUTRAL RARE GAS LASER		5. Security Classification  <input type="checkbox"/> U <input type="checkbox"/> U <input type="checkbox"/> U Document Title      Abstract  S (Secret) C (Conf) R (Rest) U (Unclass) * For UNCLASSIFIED docs with a secondary distribution LIMITATION, use (L)	6. No. of Pages 16 7. No. of Refs.
8. Author(s) Kenneth J. Grant		9. Downgrading/ Delimiting Instructions N/A	
10a. Corporate Author and Address  Electronics Research Laboratory PO Box 1500 SALISBURY SA 5108		11. Officer/Position responsible for  Security                      N/A  Downgrading                N/A	
10b. Task Sponsor  DST		Approval for release      DERL	
12. Secondary Release of this Document  APPROVED FOR PUBLIC RELEASE.  Any enquiries outside stated limitations should be referred through DSTIC, Defence Information Services, Department of Defence, Anzac Park West, Canberra, ACT 2600.			
13a. Deliberate Announcement  No limitation.			
13b. Casual Announcement (for citation in other documents) <input checked="" type="checkbox"/> No Limitation <input type="checkbox"/> Ref. by Author & Doc No only			
14. DEFTEST Descriptors Gas lasers                      Design Wavelengths                  Laser outputs		15. DISCAT Subject Codes 1709	
16. Abstract  A neutral rare gas laser has been built, and used to produce continuous wave output at several wavelengths in the mid-infra-red region. The laser design is described, and results are presented of a parametric study of its operating characteristics. Mixtures of He-Ar, He-Kr, and He-Xe were used. The output power at each wavelength was monitored as a function of the discharge parameters, to determine the optimum working regimes.  This General Document is a paper presented at the 8th Conference of the Australian Optical Society, held at the University of Sydney, NSW, in February 1993.			

Page Classification <b>UNCLASSIFIED</b>
Privacy Marking/Caveat

16. Abstract (CONT)		
17. Imprint  Electronics Research Laboratory PO Box 1500 SALISBURY SA 5108		
18. Document Series and Number  ERL-0703-GD	19. Cost Code	20. Type of Report and Period Covered  ERL General Document
21. Computer Program Used		
22. Establishment File Reference(s)		
23.T1 Additional information (if required)		